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ABSTRACT

The study discussed in this report is exploratory. It was undertaken to (1) determine the effects which age, lighting and the duration of near vision tasks have on visual accommodation; and (2) obtain vision data which could be applied to improve aircrew utilization and crew station design. The results indicated the ability to focus the eyes at infinity following the performance of near vision tasks decreases with age; and eye focussing time is related to the duration of the near vision task, and with some exceptions, increases with increase in near vision task time. Further study, utilizing larger sample sizes, is required to verify these preliminary conclusions and expand their usefulness to crew station designers.

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1.0 SUMMARY AND RECOMMENDATIONS

Insufficient emphasis has been given to the effects of age on the visual and operational performance of aircraft pilots. Vision researchers and aircraft designers have been, to some extent, aware of the depreciating clarity of near vision with advancing age, but have not thoroughly determined its effects on a pilot's operational performance.

Whether operating under instrument or visual rules of flight, pilots spend much of their time monitoring flight deck instruments which are in a near vision range. The similarity and inseparableness of many near and distant visual tasks performed during flight underline the need for understanding the interrelatedness of near and distant vision capabilities. The near-distance vision relationships discovered as a result of this study suggest re-appraisal of some accepted crew utilization concepts and crew systems design philosophies.

This study was undertaken to (1) investigate the effect of age on time required to change the focus of the eyes in acquiring an achievable quality of vision at visual infinity following performance of near vision tasks, and (2) obtain vision data which could be applied to improve aircrew utilization and crew station design. The key parameters investigated are traceable to aircraft pilots' in-flight habits for intermittent monitoring of flight deck instrumentation under varying ambient illumination levels and time durations.

The test equipment and experimental plan used during the study were carefully structured to ensure obtaining valid and operationally useful data.

Figure 1 illustrates the experimental approach. The selected parameters were kept as close as possible to real life operational conditions including varying pilot ages, external ambient lighting levels, near vision ranges, and near vision task times.

In the study, seven groups, each consisting of five subjects, were used; group ages ranged from 20 to 55 years. Two ambient illumination conditions approximated levels of solar and lunar illumination incident at sea level. Near vision ranges within the flight deck were simulated by 13- and 26-inch near vision distances. Pilots' intra-flight deck near vision tasks were represented by randomly presented task times of 30, 60, 120, and 240 seconds.

The sensitivity required to obtain accurate measurements of eye focussing time was provided by a LASER Optometer which consisted of the reflected image of a low powered gas LASER onto a slowly rotating drum. Subject view of the LASER image provided subjective awareness of the accuracy of the focus of his eyes; the LASER image appeared to scatter randomly when it was in focus, or flow in a definable direction when it was out of focus.

Using the LASER Optometer according to the approach described in Figure 1, data collection was completed in accord with the following instructions given to each subject:

(a) Look at the LASER and indicate when accurate focus is obtained;

(b) Read the printed material aloud at near;

(c) At the end of the reading period, look immediately at the LASER image;

(d) Press a button when the LASER image appears focussed (button stopped a time clock which was started at the end of the reading).

(e) Look at a screen beyond the LASER continuously until instructed to repeat (a) above.

Analysis of the data collected according to the aforementioned procedures revealed the following:

- The ability to focus the eyes at infinity following near use decreases with age. Decrease in focussing capability becomes apparent after age 35 and continues until later life; a 50-year old requires approximately three times more time to focus than a 25-year old.
- Regardless of the illumination level, eye focussing time is related to the length of the near task time and, with some exceptions, increases with increase of near task time. This relationship is most noticeable under low ambient illumination.
- Illumination level affects eye focussing time. Generally, longer eye focussing times were required under

low ambient illumination levels, being especially pronounced for age groups older than 35 years.

These results are operationally significant to crew station design and utilization of flight personnel because they indicate older pilots, needing more time to achieve adequate focus at distance, would have a disadvantage in performing tasks requiring rapid, accurate vision. This factor may contribute to reducing the probability of success in some tactical missions and could reduce the safety of normal flight operations. The results indicated, following near point use, some subjects' eyes were out of focus by as much as 0.37 diopter for varying periods of time. This could mean during some critical flight periods, a pilot's vision may be temporarily reduced from, for instance, normal vision of 20/20 to 20/25 (slight nearsightedness).

In addition to the aforementioned conclusions, this study verified the excellence of the LASER Optometer as a tool for evaluating visual behavior. The LASER technique offers, with some improvements, a method for defining degradation of crew members' vision resulting from transparency and instrument characteristics in dioptric and/or distance terms.

Using the results of this study as a basis, the following uses of the LASER Optometer technique are recommended:

o Initiate studies to define the extent to which flight deck transparencies (windshields and canopies) and instrument characteristics affect the extent and duration of visual focus.

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o Improvise means to define the operational significance of visual focus time on performance.

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2.0 INTRODUCTION

The objective of this study was to emphasize and define to some extent the importance of an aircraft pilot's age on his visual capability. Since the ages of military and commercial pilots vary from the early twenties to the sixties, a better understanding of the dependence of visual performance on age can increase the overall effectiveness of operational aircraft systems through improved selection and utilization of flying personnel and by providing engineering design criteria to compensate for visual inadequacies.

Optometrists, ophthalmologists, industrial safety personnel, vision researchers, and most persons past forty are aware of decreases in the eye's focussing ability with advancing age. The physiological process of adjusting focus to maintain clear and/or comfortable vision is called accommodation. A decrease in focussing ability (loss of accommodation) can make it difficult to quickly and comfortably obtain and sustain a desired quality of vision. The considered significance of this condition to safe, successful flight operations resulted in initiation of this study to investigate the effect of age on time required to achieve ocular focus at visual infinity following use of the eyes for near vision tasks.

3.0 METHOD

The experimental approach used during this study is shown in Figure 1. The approach required a systematic evaluation of the effects of age on time required to change the focus of the eyes by comparing results obtained for each of seven different age groups under identical test conditions of: (1) two ambient illumination levels; (2) two near point reading distances; and (3) four near point reading times.

Prior to implementing the details of the plan, two sets of criteria which could affect the fidelity of the results had to be satisfied. These criteria pertained to:

- o Test equipment
- o Subjects

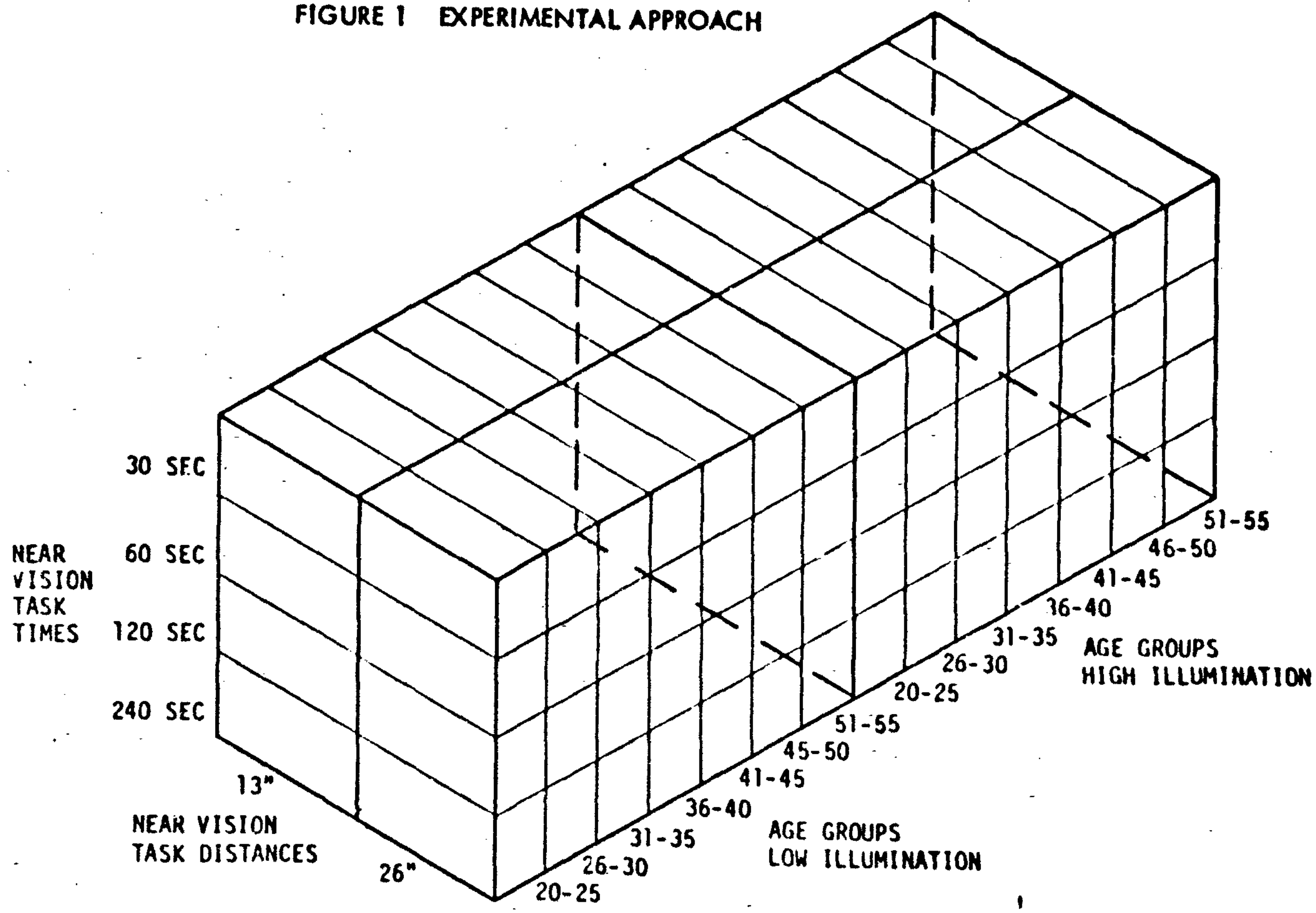
3.1 TEST EQUIPMENT

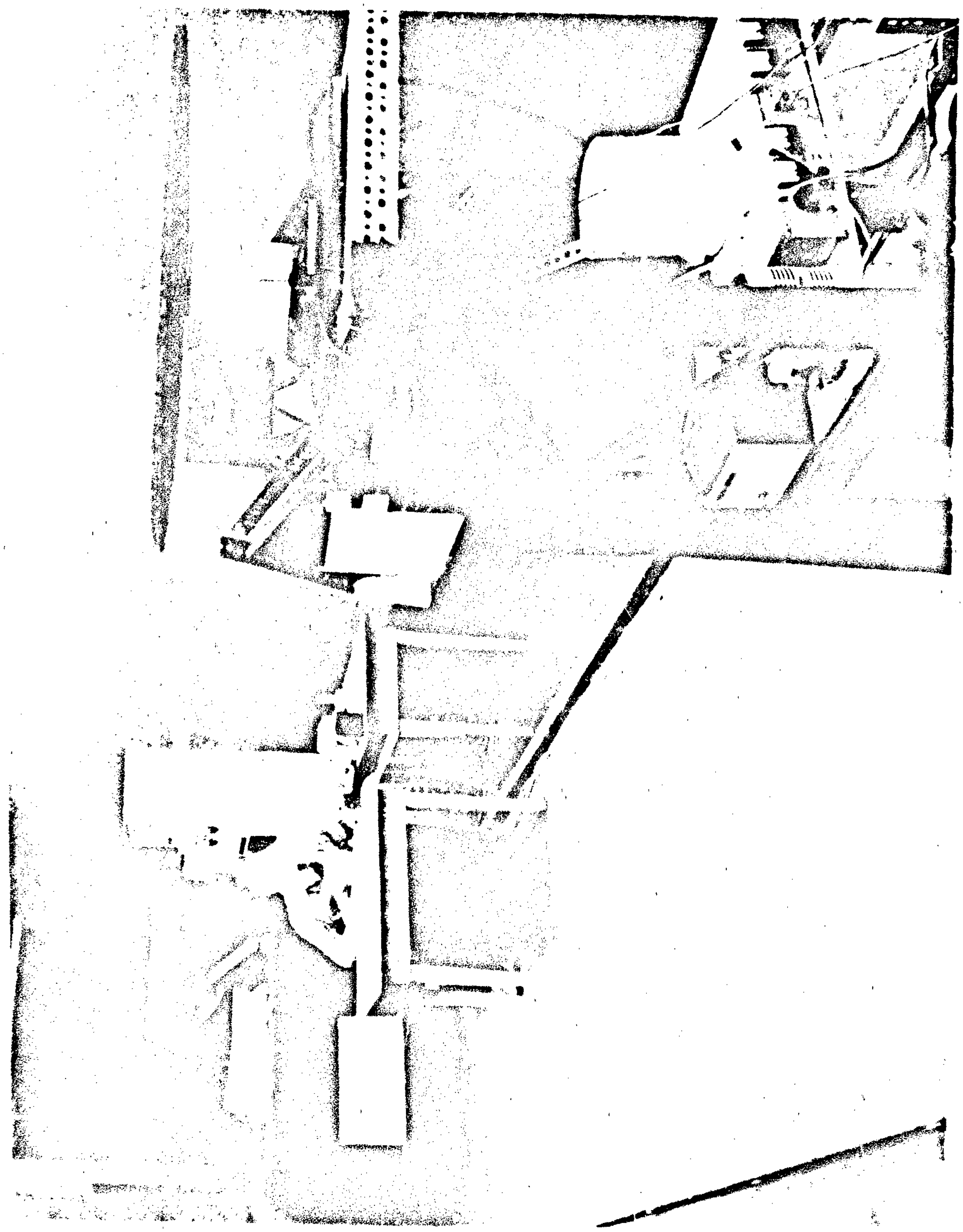
Test equipment used in this study consisted of (1) a low-powered gas LASER and accessory equipment; (2) near point stimulus material; (3) two time clocks; (4) subject control booth and accessories; (5) trial frame and trial lens sets; and (6) experimenter's control station (Figure 2).

All the equipment, except the LASER and accessories, were simple and routine.

The use of LASERs as optometers (instruments for measuring the refractive state of the eye) did not originate with

FIGURE 1 EXPERIMENTAL APPROACH





this study, even though the application to study accommodation as expressed in this report is unique. Objectives of earlier studies were to investigate the use of the LASER Optometer as a technique for determining the extent of ametropia (nearsightedness, farsightedness, astigmatism) and as an aid in the fitting of eyeglasses. Knoll[8.1], in explaining the appearance of the LASER image when used as an optometer, adequately summarized descriptions given by Rigdon and Gordon[8.2], and Oliver[8.3], as well as his own with the following statement which offers, for purposes of this report, as good a description of the appearance of the LASER image as any.

> "Rigdon and Gordon[1] and Oliver[2] have explained the appearance of the pattern. When coherent light from the LASER hits a surface, it becomes scattered and produces real images of randomly changing interference patterns in front of the scattering surface and similar virtual images behind the surface. The particular pattern seen is determined by the point in space that is conjugate to the observer's retina. Moreover, when the observer moves his head laterally, the pattern appears to move in the same direction as his head if the retinal conjugate lies behind the scattering surface, and opposite to his head movement if the conjugate is in front of the surface. Lenses placed before the observer's eye can eliminate this apparent movement of the LASER pattern and can thereby neutralize any ametropia of the eye with respect to the scattering surface.
>
> "Some observers have difficulty seeing the motion of the pattern while moving their heads. I have found that this motion can be more easily seen if the head is stationary and the surface, upon which the LASER spot is projected, is slowly moved. With a slowly rotating cylindrical drum as the surface, the random interference pattern sweeps past the eye and the observer can readily see the direction of the apparent motion. The head must be held very still, otherwise the motions will be compounded and the results confused."

The LASER Optometer used in this study consisted of a diverged beam of a low-powered gas LASER reflected from two plano mirrors onto a rotating drum.

Speed of the drum and size of the image were fixed to allow easy viewing. The most satisfactory drum speed and image size were determined through preliminary testing.

When viewed from a distance, the LASER image was easy to observe. It scattered randomly if the eyes were adequately focussed; or flowed in some definite direction (left, right, up, down, or diagonally) if the viewer's eyes were inadequately focussed. The characteristics of the LASER image could be clearly identified and responded to with confidence.

3.2 SUBJECTS

The thirty-five subjects used in this study demonstrated the ability to easily discern (1) the "random scattering" appearance of the LASER image when, with or without corrective lenses, the eyes were adequately focussed as required, and (2) the "flowing or streaming" movement when the eyes were inadequately focussed. The thirty-five subjects were selected from among the more than 50 screened.

Clinical optometric procedures were utilized during the subject selection process to identify the subjects' ametropia (ocular refractive state) and ease of binocular coordination, and to minimize the extent of their influence on visual performance.

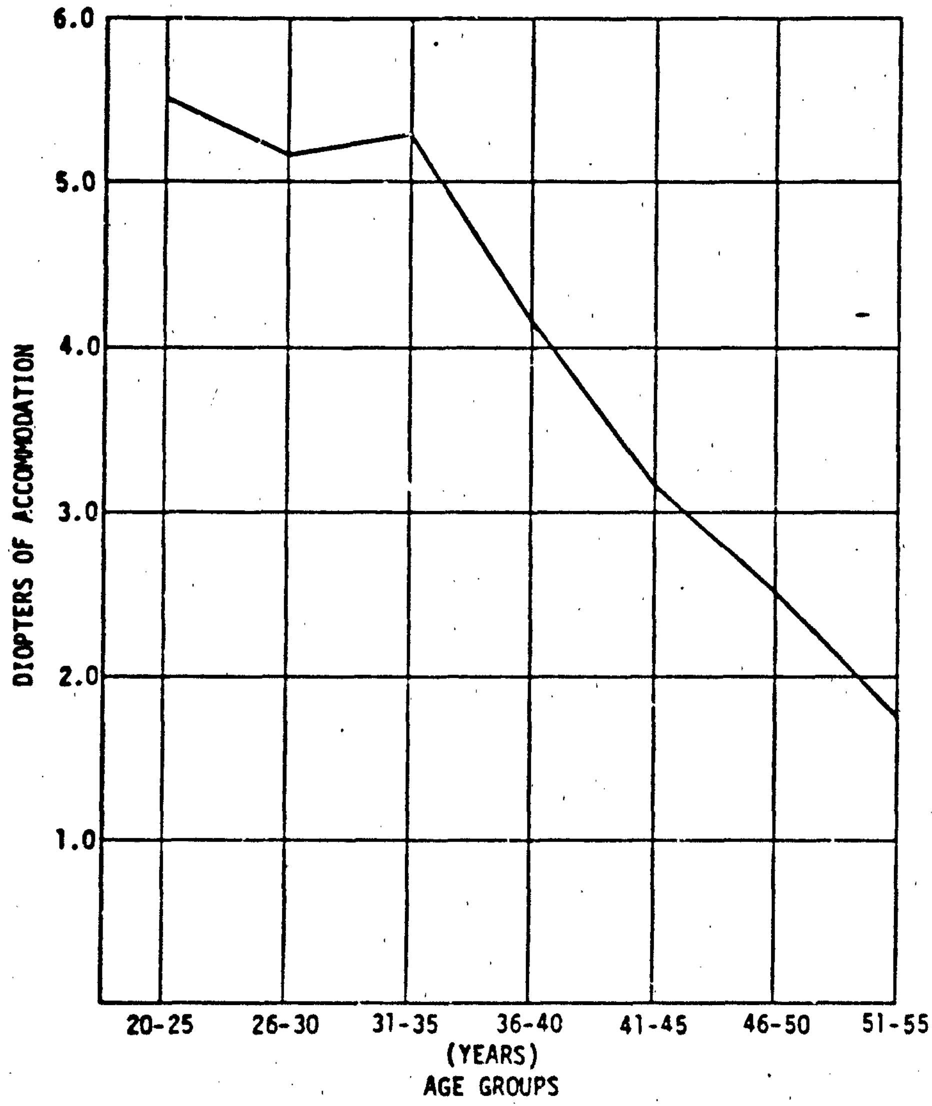


FIGURE 3
THE EFFECTS OF AGE ON AMPLITUDE OF ACCOMMODATION

Table 1. Lens Corrections Obtained for Best Vision by Conventional and LASER Optometer Refractions

* Subject's Age

Subjects	Best Lens Correction - Right Eye: Conventional Refraction	Best Lens Correction - Right Eye: LASER Refraction	Best Lens Correction - Left Eye: Conventional Refraction	Best Lens Correction - Left Eye: LASER Refraction
1.(22)*	Plano	Plano	Plano - .25 x 180	Plano - .25 x 180
2.(22)	+0.25 - .37 x 130	+0.37 - .25 x 130	+0.25 - .37 x 160	+0.25 - .25 x 160
3.(24)	+0.50 - .37 x 100	+0.25 - .25 x 100	+0.50 - .37 x 70	+0.37 - .25 x 70
4.(24)	-0.75 - .50 x 90	-0.87 - .50 x 90	-0.75 - .25 x 102	-1.00 - .25 x 95
5.(25)	-1.37	-1.37	-1.37	-1.37
6.(26)	Plano - .75 x 95	Plano - .75 x 95	Plano - .75 x 95	Plano - .75 x 95
7.(27)	-1.00 - .37 x 180	-0.75 - .25 x 180	-1.50 - .37 x 165	-1.25 - .25 x 165
8.(28)	Plano - .37 x 90	Plano - .25 x 90	Plano	Plano
9.(29)	-2.50 - .37 x 85	-2.50 - .25 x 95	-2.50 - .37 x 120	-2.25 - .25 x 125
10.(30)	Plano - .12 x 90	Plano	Plano	Plano
11.(31)	Plano - .75 x 80	Plano - .75 x 80	Plano - .75 x 95	-0.37 - .50 x 95
12.(31)	-3.25 - .37 x 165	-3.00 - .25 x 165	-3.50	-3.37
13.(31)	Plano - .12 x 65	Plano - .25 x 65	Plano - .37 x 110	Plano - .25 x 110
14.(32)	Plano - .37 x 75	-0.37 - .25 x 75	-0.25 - .62 x 125	-0.37 - .50 x 125
15.(32)	Plano - .75 x 90	Plano - .25 x 90	Plano - .37 x 90	-0.25 - .25 x 90
16.(38)	-1.75 -2.75 x 38	-1.75 -2.50 x 35	-2.25 -2.00 x 175	-1.87 -2.00 x 175
17.(39)	+0.25 - .50 x 172	+0.50 - .50 x 175	Plano - .37 x 10	+0.12 - .25 x 10
18.(39)	+0.75	+0.75 - .25 x 65	+0.50 - .62 x 162	+0.50 - .50 x 165
19.(40)	+0.87 - .37 x 90	+0.75 - .25 x 90	+0.87 - .37 x 90	+0.75 - .75 x 90
20.(40)	-0.25 - .37 x 150	-0.25 - .25 x 150	-1.50	-1.50
21.(41)	+0.50	+0.62	+0.50	+0.62
22.(41)	-3.50 - .37 x 15	-3.50 - .75 x 15	-3.50 - .87 x 165	-3.50 - .75 x 165
23.(44)	-0.75 - .62 x 180	-0.75 - .75 x 180	-0.75 -1.62 x 145	-0.50 -1.50 x 145
24.(45)	-5.00 - .25 x 10	-5.00 - .25 x 10	-5.00 - .37 x 175	-4.75 - .37 x 175
25.(45)	-0.50 - .50 x 135	-0.25 - .50 x 135	-0.25 -1.00 x 37	-0.50 -1.00 x 45
26.(47)	+0.25 -1.12 x 95	+0.25 -1.00 x 95	Plano - .37 x 75	Plano - .25 x 75
27.(49)	Plano - .75 x 10	+0.12 - .75 x 10	+0.25 -1.00 x 170	+0.25 -1.00 x 170
28.(50)	+1.75	+1.75	+1.75 - .37 x 160	+1.75 - .25 x 160
29.(50)	+0.75 - .62 x 170	+0.75 - .50 x 170	+0.75 - .25 x 135	+0.75 - .25 x 135
30.(50)	-1.50 - .37 x 165	-1.62 - .25 x 165	-1.75 - .87 x 05	-1.87 - .75 x 05

Table 1 (Contd)
Lens Corrections Obtained for Best Vision by Conventional and LASER Optometer Refractions

Subjects	Best Lens Correction - Right Eye		Best Lens Correction - Left Eye	
	Conventional Refraction	LASER Refraction	Conventional Refraction	LASER Refraction
31.(51)	-0.25 -1.37 x 105	Plano -1.25 x 105	Plano -1.37 x 75	-0.37 -1.25 x 75
32.(51)	-0.12 - .37 x 75	-0.12 - .25 x 70	-0.87 - .50 x 170	-0.62 - .50 x 170
33.(52)	+0.50 - .62 x 125	_0.50 - .50 x 125	_0.75 - .37 x 95	_0.75 - .25 x 95
34.(53)	Plano	Plano	-0.37	-0.37
35.(53)	+0.50 - .50 x 70	+0.50 - .50 x 70	+0.12	+0.12

Subjects were screened optometrically to determine the (1) nature and magnitude of the refractive error, (2) amplitude of accommodation, and (3) quality of binocular coordination. Prospective subjects manifesting more than 3.0 diopters of astigmatism (regardless of axis) or gross binocular coordination difficulties (over convergence, under convergence, vertical unparallelism, suppression) were eliminated because of the possible unwanted influences these conditions may have on eye focussing time. Only three subjects manifested astigmatism in excess of 1.25 diopters.

The thirty-five subjects were divided into seven equal groups. Group ages varied from the youngest of 20-25 years of age to the oldest, 50 to 55. All subjects were male.

Since it is a generally accepted fact that eye focussing ability declines with age, selecting groups by age was equated to selecting groups according to eye focussing ability. Figure 3 demonstrates how eye focussing ability declined with advancing age for the subjects used. Table I lists the lens corrections required for best visual acuity and for obtaining randomly scattered non-directional LASER image movement (adequate focus of the eyes).

3.3 EXPERIMENTAL PROCEDURE

With the equipment and subject criteria satisfied, the procedures listed below were used to study the conditions described in Figure 1.

1) The purpose of the study was explained to each subject before the start of the test.
2) Each subject was seated in the subject control booth with chin in chin rest and fitted with an American Optical Trial Frame and the corrective lenses required to obtain adequate focus of the LASER image located 20 feet (visual infinity) away; adequate focus was obtained for monocular and binocular conditions.
3) Subjects were instructed in the appearance of various inadequately focussed LASER images. This was done by adding at different times at least each of four lenses (+0.25, -0.25, +0.37, -0.37) to the lens corrections of the left and right eye during monocular and binocular observance of the LASER image.
4) While wearing the lens correction which provided adequate focus, further instructions were:
   a) Observe the LASER image until ordered to read aloud pre-selected printed materials presented at the near point and continue until advised to "stop".

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b) At the command "stop", look again continuously at the LASER image as long as any of the inadequate focus appearances illustrated with lenses in 3) above persist.

c) Press a hand-held button as soon as the LASER image appears adequately focussed.

d) Look immediately at a homogeneous screen located behind the LASER image and maintain this point of gaze until instructed to look again at the LASER.

e) Maintain adequate focus until ordered to read.

5) Two time clocks were used; the starting and stopping of one was under the exclusive control of the experimenter and was used to measure the duration of subject's near point reading periods. The second clock was controlled by both experimenter and subject; it was started by the experimenter at the end of the subject's reading time (start of LASER image observation) and stopped by the subject when the LASER image first appeared adequately focussed.

6) The elapsed time between the start of the second clock by the experimenter and its stopping by the subject provided a measure of the time required to focus the eyes following near point usage.

These procedures were followed for each of the seven groups of subjects and conditions shown in Figure 1 which included two ambient illumination levels, two near point reading distances (13", 26") and four near point reading times (30 sec., 60 sec., 120 sec., 240 sec.).

4.0 RESULTS

Tables 2 and 3 are tabulations of raw data collected during the study. Results of statistical analysis of the raw data are shown in Tables 4, 5, 6, and 7. See Appendix, Paragraphs 9.1 and 9.2. The data plots illustrated in Figures 4 through 11 express, almost in all cases, a large degree of variability which, to some extent, was expected because of (1) the small sample size and (2) the human vision parameter tested.

The general value and significance of the study can be easily assessed through a detailed discussion of the data plotted in the figures. Even without more sophisticated tests of statistical significance, plots of the means and standard deviations as illustrated in Figures 4 through 11 and Tables 4 through 7 allow self-explanatory reader assessment of the significance of the findings. The figures allow the following salient comparisons:

- The effects of the duration of near vision task time on eye focussing time under low illumination. Variables include seven different age groups at near work distances of 13 and 26 inches (Figures 4 and 5).
- The effects of the length of near vision task time on eye focussing time under high illumination. Variables include seven different age groups at near work distances of 13 and 26 inches (Figures 6 and 7).

- The effects of age on eye focussing time at two illumination levels for near vision task distances of 13 and 26 inches (Figures 8 and 9).
- The effects of age on eye focussing time at two illumination levels for an averaged (13 and 26 inches) near vision task distance (Figure 10).
- The effects of age on eye focussing time for near vision task distances of 13 and 26 inches at an averaged illumination level (Figure 11).

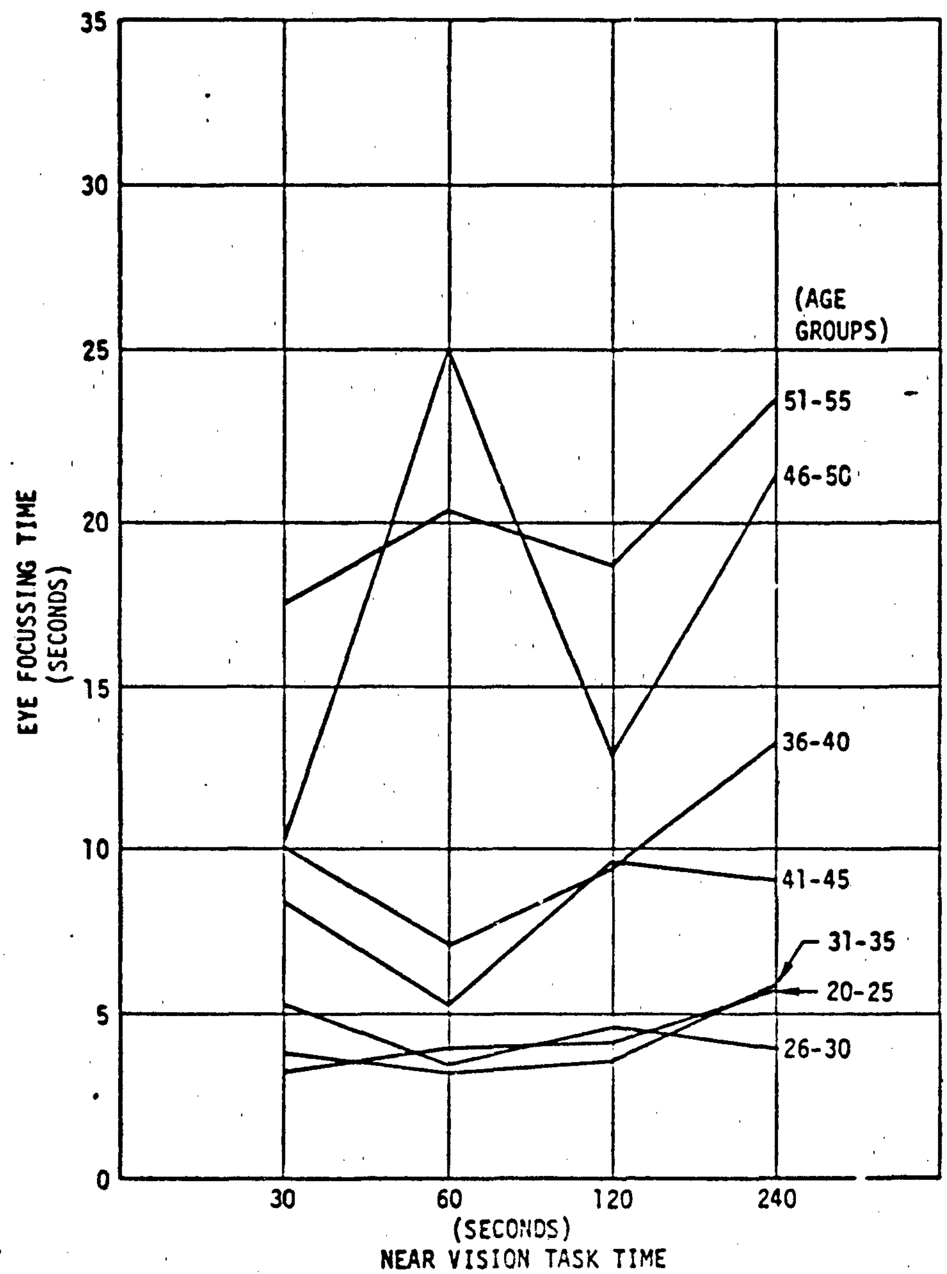

FIGURE 4
THE EFFECTS OF NEAR VISION TASK TIME ON EYE FOCUSSING TIME UNDER LOW ILLUMINATION FOR A 13-INCH NEAR VISION TASK DISTANCE

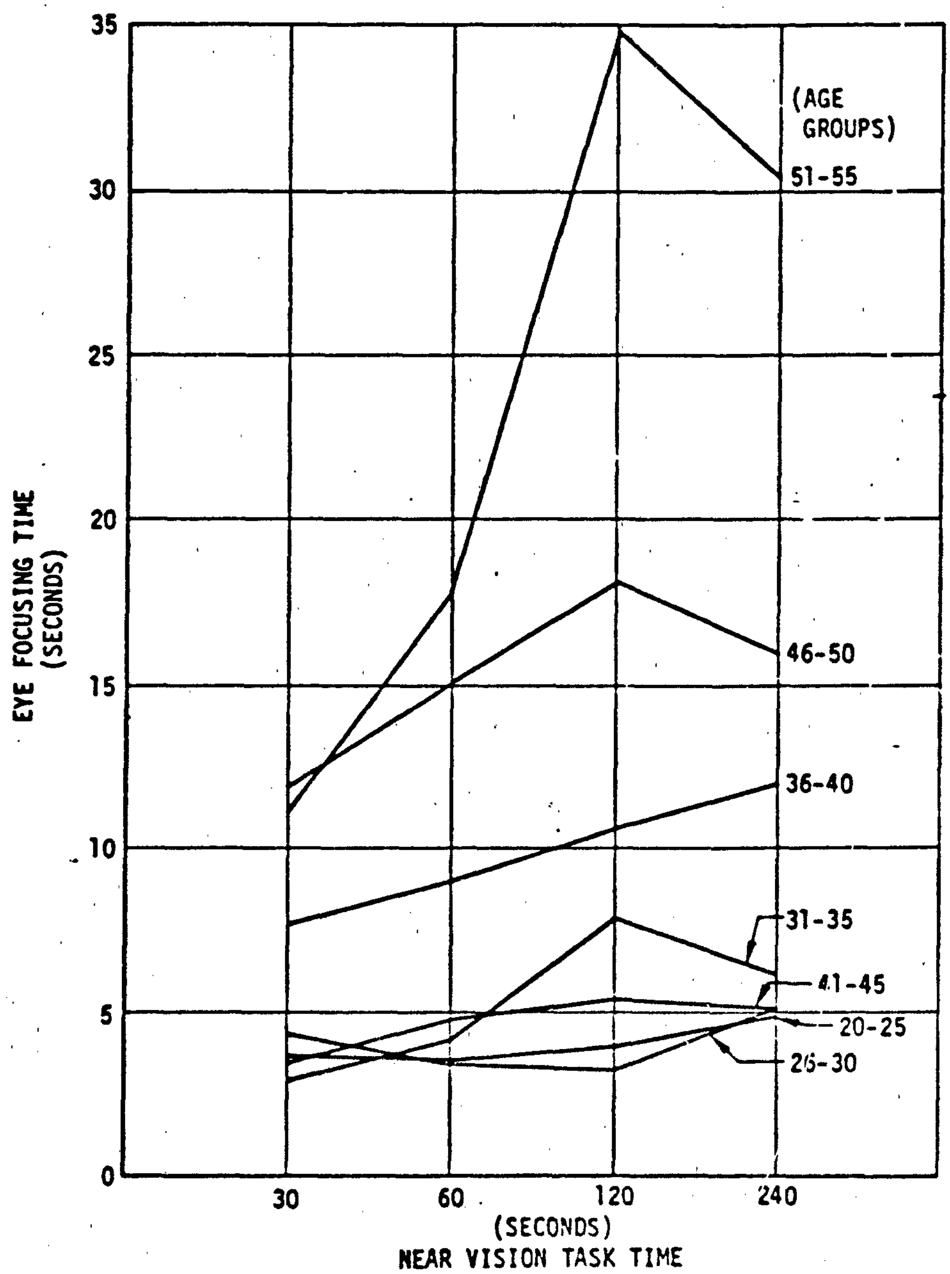

FIGURE 5
THE EFFECT OF NEAR VISION TASK TIME ON EYE FOCUSSING TIME UNDER LOW ILLUMINATION FOR A 26-INCH NEAR VISION TASK DISTANCE

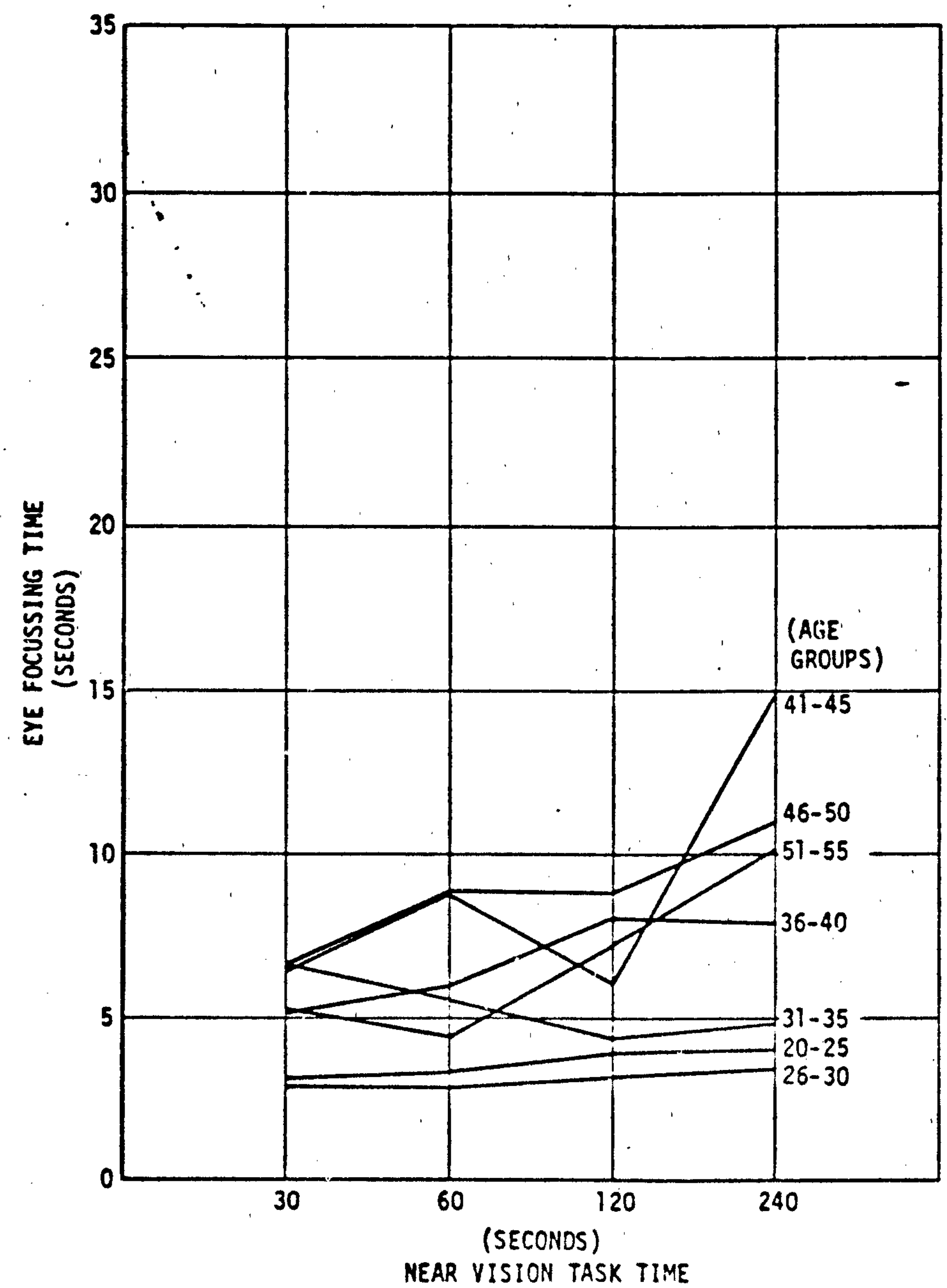

FIGURE 6
THE EFFECTS OF NEAR VISION TASK TIME ON EYE FOCUSSING TIME FOR A NEAR VISION TASK DISTANCE OF 13 INCHES UNDER HIGH ILLUMINATION LEVEL

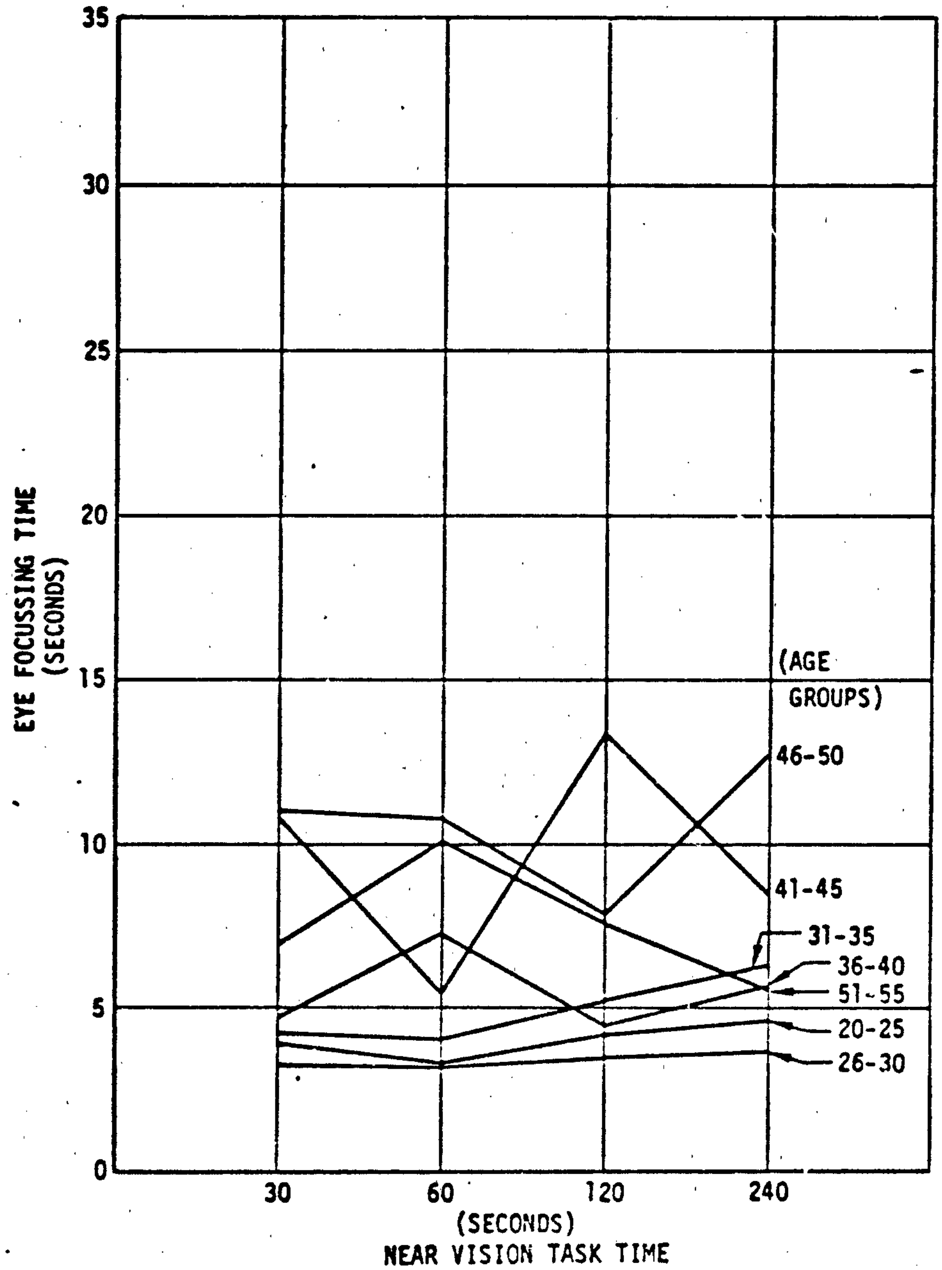

FIGURE 7
THE EFFECTS OF NEAR VISION TASK TIME ON EYE FOCUSSING TIME FOR A NEAR VISION TASK DISTANCE OF 26 INCHES UNDER HIGH ILLUMINATION LEVEL

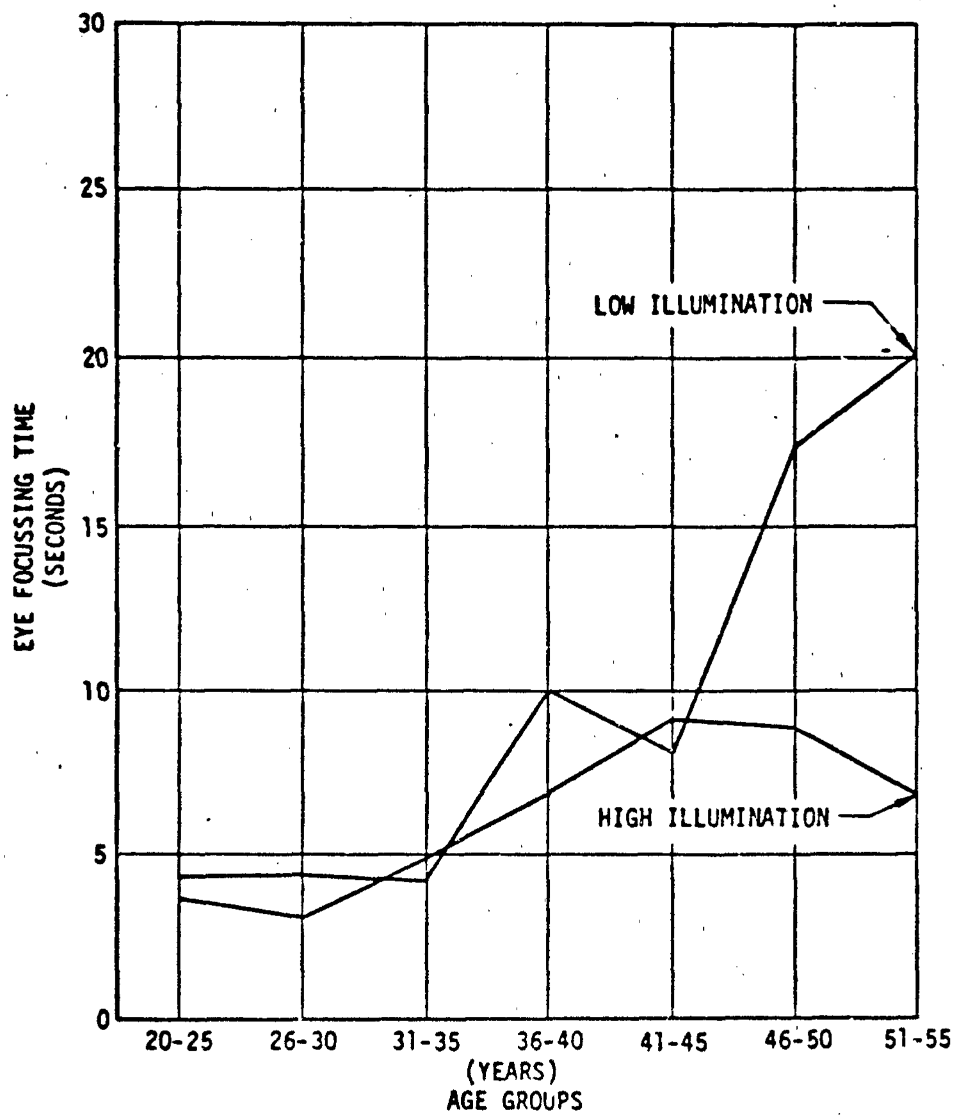

FIGURE 8
THE EFFECTS OF AGE ON EYE FOCUSSING TIME FOR NEAR VISION TASK DISTANCE OF 13 INCHES UNDER TWO ILLUMINATION LEVELS

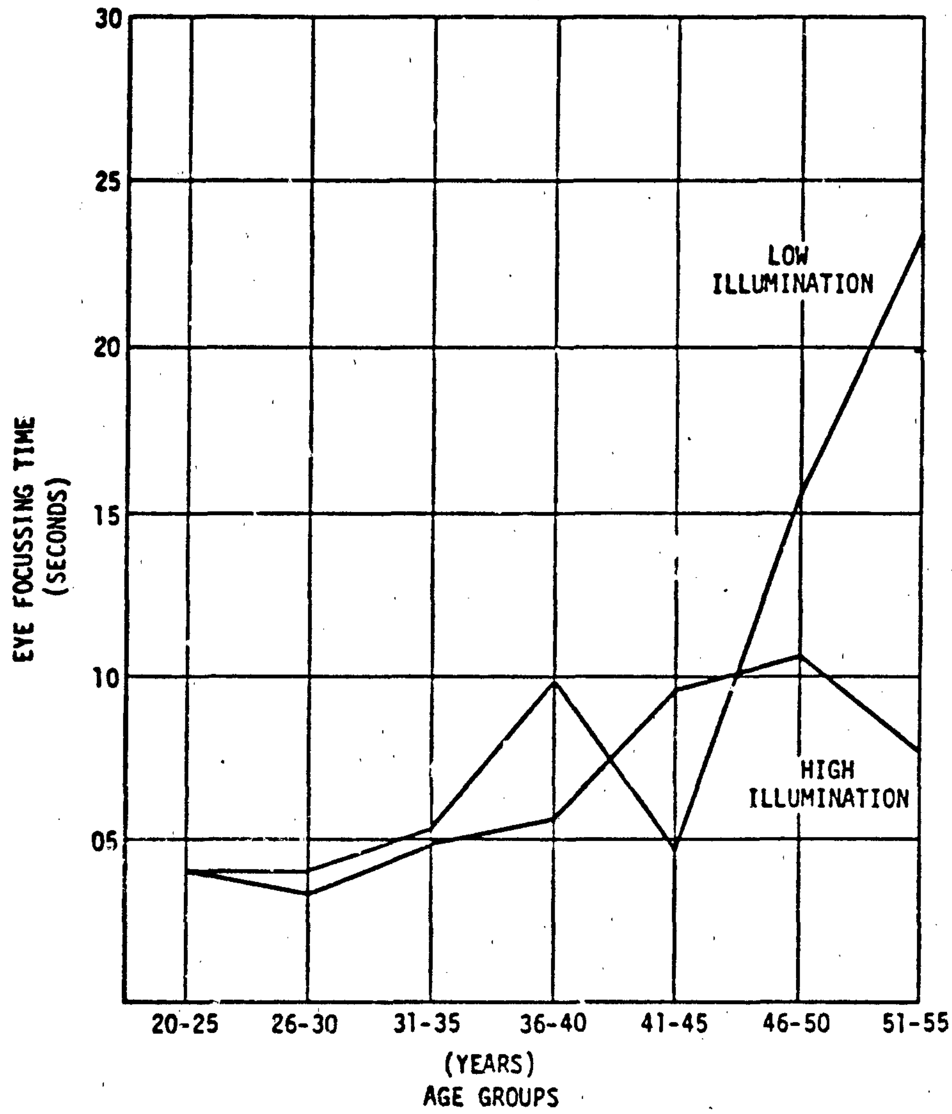

FIGURE 9
THE EFFECTS OF AGE ON EYE FOCUSSING TIME FOR A NEAR VISION TASK DISTANCE OF 26 INCHES UNDER TWO ILLUMINATION LEVELS

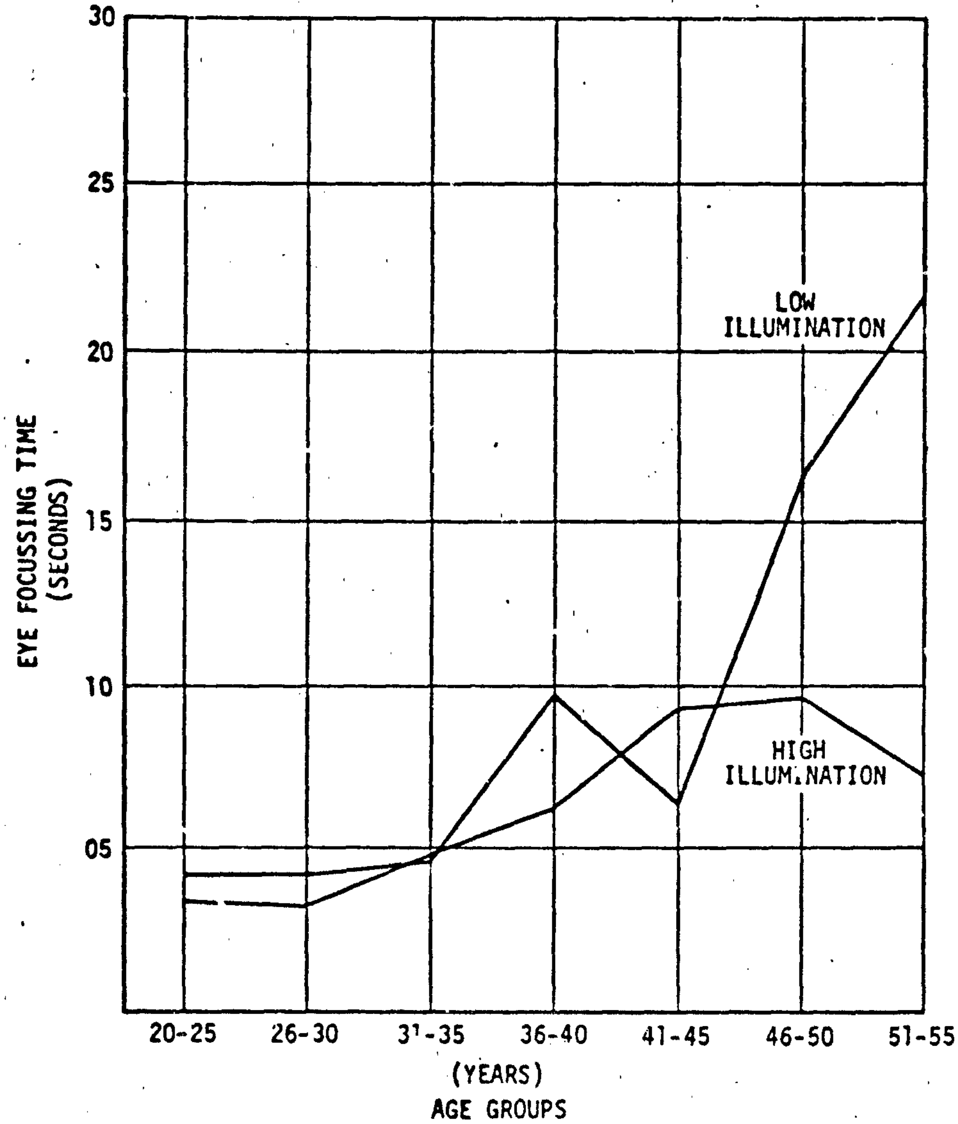

FIGURE 10
THE EFFECTS OF AGE ON EYE FOCUSSING TIME FOR AN AVERAGE NEAR VISION TASK DISTANCE

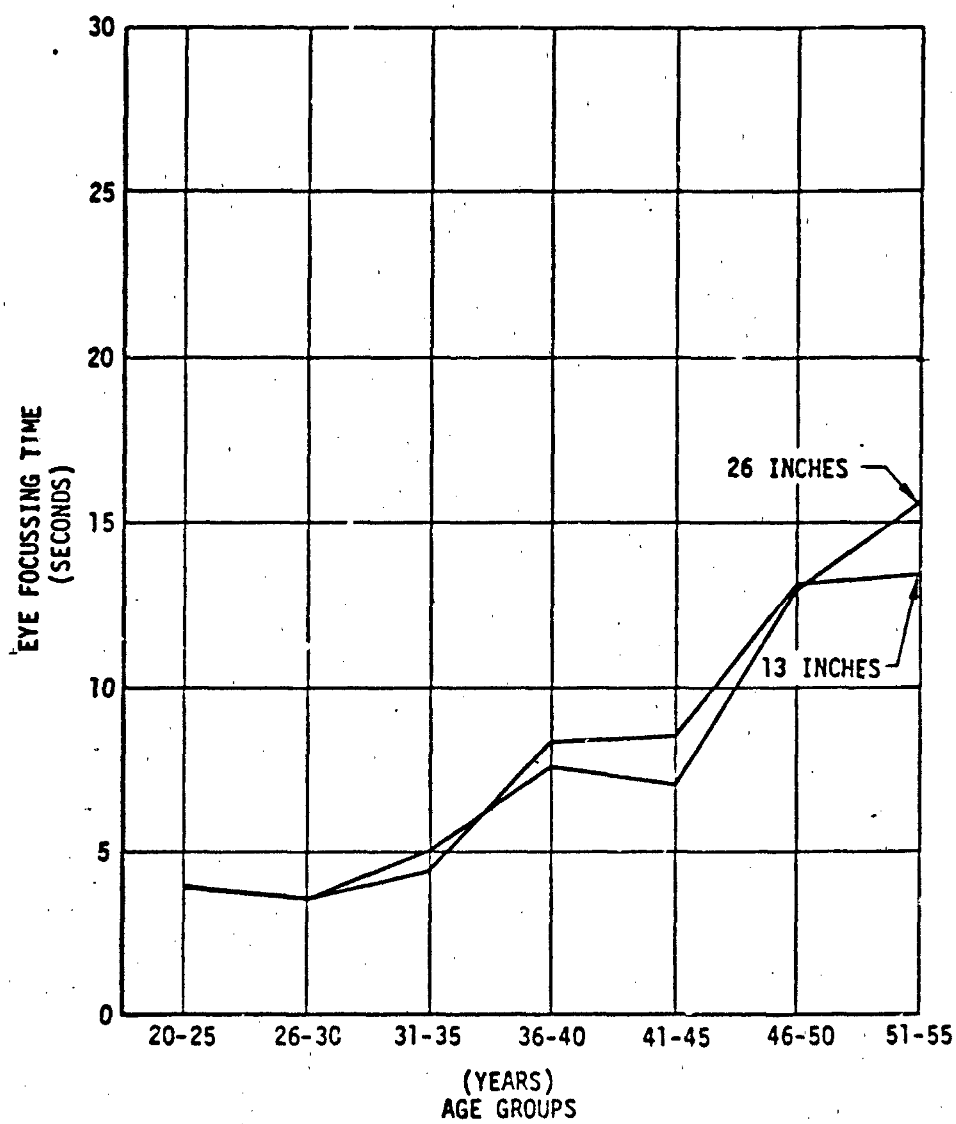

FIGURE 11
THE EFFECTS OF AGE ON EYE FOCUSSING TIME FOR AN AVERAGED ILLUMINATION LEVEL

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5.0 DISCUSSION

Obviously, the raw data summarized in Tables 2 and 3 permitted many other treatments in addition to the ones listed in Section 4.0. However, the summary included in this section expresses the significance of the key study findings.

EFFECTS OF THE DURATION OF NEAR VISION TASK TIME ON EYE FOCUSSING TIME UNDER LOW ILLUMINATION

Time required to focus the eyes following near task times of 30 sec., 60 sec., 120 sec., and 240 sec. were averaged for each of the seven age groups at near vision task distances of 13 (Figure 4) and 26 inches (Figure 5) under a low illumination setting. Figures 4 and 5 show eye focussing time increases with increase in near vision task time. This was true for all near vision task times except the 60-second one. A comparison of eye focussing times for the 30-second and 60-second near vision tasks for each of the seven different age groups indicated that in only three cases were eye focussing times for the 60-second near vision task higher than that for the 30-second one. However, eye focussing times for the 120-second and 240-second near work times were higher than the 30-second time for all cases in the seven groups compared except two. These findings indicate an almost direct relationship between near vision task time and eye focussing time; in general, the eyes require more time to focus following near work of 2 minutes or more than for near work time increments less than a

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minute.

Since closer near vision task distances and longer near vision task times were expected to tax accommodation more than shorter near vision task distances and times under identical test conditions, longer eye focussing times were expected for the near vision tasks which were closer and of longer durations. Longer eye focussing times were expected for the 13-inch, 60-second near vision task than for the 13-inch, 30-second task. Likewise, longer eye focussing times were expected for the 26-inch, 60-second task than for the 26-inch, 30-second task. However, these expectations were not substantiated by comparisons of eye focussing times for the low illumination 13-inch, 30-second and 60-second tasks (Figure 4) and 26-inch, 30-second and 60-second tasks (Figure 5). Compare results in Figures 4 and 5. It is interesting to note the 13-inch, 60-second and the 26-inch, 60-second eye focussing times for the 46-50 and 51-55 age groups were consistently longer than the 13-inch, 30-second and 26-inch, 30-second tasks for the same groups. The opposite was almost totally true for the two youngest age groups (20-25, 26-30).

The variability of the data in Figures 4 and 5 suggests (1) near vision task distances and times affect eye focussing times least for the 20-30 year olds and (2) particularly, near vision task times less than 1 minute affect eye focussing times less for the 20-25 and 26-30 year age groups than for the 45-50 and 51-55 age groups.

EFFECTS OF THE DURATION OF NEAR VISION TASK TIME ON EYE FOCUSSING TIME UNDER HIGH ILLUMINATION

The duration of near vision tasks has a direct effect on eye focussing times at high levels of illumination (Figures 6 and 7). This is truer for the 20-25 and 26-30 year age groups than all the others at both the 13-inch and 26-inch near vision task distances. For both of these groups increase in eye focussing time is directly related to the duration of the near vision task time. Greater variability is expressed for the older groups (31 and above). Eye focussing time for all age groups is longer for the 13-inch, 240-second near vision task time than the 13-inch, 30-second period, except one. However, for the 26-inch distance, eye focussing time for the 240-second near vision task is longer than the 30-second period five out of seven times.

EFFECTS OF AGE ON EYE FOCUSSING TIME AT TWO ILLUMINATION LEVELS FOR 13-INCH AND 26-INCH NEAR VISION TASK DISTANCES

Figures 8 and 9 illustrate the effects of age on eye focussing time for 13- and 26-inch near vision task distances. The data are plotted for high and low ambient illumination settings. The plots represent the mean of the focussing times obtained for all (30 sec., 60 sec., 120 sec., and 240 sec.) near vision task times for the five subjects in each group.

Figures 8 and 9 indicate eye focussing time is directly affected by age. The effects of age are more pronounced at the low ambient illumination setting for the 13-inch and 26-inch near vision task distances. Eye focussing times at the low ambient illumination setting were appreciably shorter than eye focussing times at the high illumination setting for the 26-30, 31-35, and 41-45 year age groups (Figures 8 and 9). Illumination level affected eye focussing times most for age groups older than 35 years. Eye focussing times were especially higher at the low illumination level for the 46-50 and 51-55 year age groups.

EFFECTS OF AGE ON EYE FOCUSSING TIME AT TWO ILLUMINATION LEVELS FOR AN AVERAGED NEAR VISION TASK DISTANCE

Each group's performance at the 13-inch and 26-inch near vision task distances were combined to obtain the plots shown in Figure 10. The plots represent mean performance for the low and high ambient illumination conditions.

As expected, shape of the curves for high and low ambient illumination conditions are quite similar to those in Figures 8 and 9.

EFFECTS OF AGE ON EYE FOCUSSING TIME FOR 13- AND 26-INCH NEAR VISION TASK DISTANCES FOR AN AVERAGED ILLUMINATION LEVEL

Figure 11 shows the effect of age on eye focussing time for 13- and 26-inch near vision task distances. Each plot on the curve was obtained by averaging the mean performance for the low and high illumination levels.

At both near vision task distances, eye focussing time increases from app.oximately 4.0 seconds for the 20-25 year age group to above 13 seconds for the 50-55 year age group.

USE FOR TYPEWRITTEN MATERIAL ONLY

6.0 CONCLUSIONS

This study verified the excellence of the LASER Optometer as a sensitive tool for studying visual accommodation. Variability expressed in the data is considered a reflection of the parameter studied (visual accommodation) and the sample size rather than the technique used. Throughout the study, almost without exception, the response of each subject to the LASER Optometer technique was one of comprehension and certainty.

Beside the verification of the usefulness of the LASER Optometer technique to study human visual behavior, other salient conclusions which can affect crew utilization in aircraft systems were reached.

The objective of the study summarized in this report and reflected in the conclusions was to acquire vision data which could be useful in improving aircrew utilization. Consequently, the key parameters investigated are traceable to aircraft pilot's inflight habits for monitoring flight deck instrumentation under varying ambient illumination levels and time durations.

The following general conclusions were reached:

- o The ability to focus the eyes at infinity following near work decreases with age. Decrease in focussing capability becomes apparent after age 35 and continues until later life; a 50-year old requires approximately three times longer to focus than a 25-year old.

o Regardless of the illumination level, eye focussing time is related to the duration of the near vision task which, with some exceptions, increases with increase of near vision task time. This relationship is most noticeable under low ambient illumination.

o Illumination level affects eye focussing time. Generally, longer eye focussing times were required under low ambient illumination levels, being especially pronounced for age groups older than 35 years.

Because the results and conclusions of this study are stated in terms of comparative eye focussing times, an explanation of the operational significance of the conclusions is presented within the context of the following question:

> What is the operational significance of a 50-year old pilot requiring, when compared to a 25-year old, three times longer to focus at distance following four minutes or less of near vision tasks (intra-flight deck)?

To determine the operational significance of the eye focussing time measure, it is important to know the point of focus before adequate focus is obtained. This requires a dioptric measure of ocular refractive state, or a distance measure of the point of inadequate focus (point other than LASER image). However, from the beginning, no plans were made to obtain dioptric or distance measures of inadequate focus. Fortunately, dioptric value estimates can be obtained from the results of a sub-study which was undertaken to determine whether a subject's dominant eye was more sensitive than the non-dominant eye to positive and negative stimulations to accommodation during binocular viewing. This sub-study was an extension of the subject's LASER image familiarization training (See Section 3.3).

The role of eye dominance in ocular response to lens stimuli to accommodation was determined for each subject wearing his correction which provided adequate focus of the LASER image (Tables 8 through 14). See Appendix, Paragraph 9.3. With the correction for best viewing (adequate focus) of the LASER image in place, low power plus and minus spherical lenses (±0.25, ±0.37) were alternately presented before the dominant and non-dominant eye to determine the minimum lens power required to elicit subject awareness of inadequate focus.

The lens power required to elicit just noticeable inadequate focus varied from ±0.25 to ±0.37 of a diopter in most subjects (See Tables 8 through 14). Operationally, these values suggest the subject's eyes, depending on age, were out of focus by as much as .37 of a diopter following near vision use. Older pilots, needing more time to achieve adequate focus at distance, would be greatly disadvantaged in performing tasks requiring rapid, acute sight.

The extent to which this factor has been responsible in military aviation for scrubbed or unsuccessful tactical missions is unknown.

7.0 RECOMMENDATIONS

To a large extent, this study verified:

- o The usefulness of the LASER Optometer as a tool for studying human visual behavior; and
- o The stated hypothesis: The time required to focus to visual infinity following near vision tasks of four minutes or less is generally longer for persons older than 35 years of age than those younger, especially at low illumination levels.

The LASER technique offers, with some improvisation, a method for defining maximum levels of inadequate focus resulting from transparency (windshields and canopies) and instrument characteristics in dioptric and/or distance terms.

With the confidence gained from this study, the following uses of the LASER Optometer technique are recommended:

- o Initiate studies to define the extent to which flight deck transparencies (windshields and canopies) affect crew performance, particularly during the target acquisition and attack portions of missions.
- o Improvise means to define the operational significance of visual focus time on crew performance.
- o Establish design criteria to improve crew visual efficiency.

USE FOR TYPEWRITTEN MATERIAL ONLY

8.0 REFERENCES

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9.0 APPENDIX

9.1 RAW DATA - PRIMARY STUDY

Tables 2 and 3 are compilations of raw data obtained for each subject for the 13- and 26-inch near vision task distances.

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Distance Focus Time (Near - 13")

SUBJECT	AGE	Hi Illumination 30 SEC.	60 SEC.	120 SEC.	240 SEC.	Lo Illumination 30 SEC.	60 SEC.	120 SEC.	240 SEC.
1	22	2.19	2.32	2.65	2.52	2.95	3.07	3.00	7.22
2	22	2.07	3.49	2.58	2.53	2.71	2.76	3.95	6.94
3	24	2.64	1.98	3.05	2.13	1.84	1.87	2.53	2.57
4	24	4.31	3.58	5.10	7.70	5.13	6.77	6.54	7.60
5	25	3.98	5.06	6.60	5.42	3.82	5.51	4.95	4.31
6	26	3.00	3.16	2.80	3.46	2.56	3.10	3.35	4.86
7	27	2.13	3.95	4.24	4.42	4.96	4.22	6.46	6.00
8	28	1.80	1.75	1.72	3.81	4.50	4.00	4.05	3.09
9	29	5.30	3.35	4.55	2.43	12.00	3.79	5.10	3.33
10	30	1.80	1.69	2.22	2.98	2.50	2.43	4.13	2.53
11	31	9.26	7.22	6.00	5.50	6.27	6.87	6.06	4.42
12	31	0.60	2.36	5.00	2.48	2.17	2.00	3.47	2.95
13	31	9.41	13.60	6.15	10.30	4.27	2.77	4.00	15.80
14	32	2.58	3.19	2.92	3.65	3.42	3.37	3.84	3.77
15	32	1.00	1.65	1.47	2.06	2.95	1.30	0.61	2.54
16	38	2.00	1.87	1.73	2.53	2.06	1.82	3.05	3.83
17	39	2.18	2.25	1.51	5.23	2.17	2.78	4.28	3.88
18	39	11.78	3.92	3.49	6.82	9.25	3.64	6.26	5.77
19	40	6.25	19.50	30.16	21.89	34.86	24.98	30.46	48.84
20	40	3.74	2.64	3.68	3.25	1.75	2.42	3.04	4.05
21	41	2.25	2.19	1.80	2.70	2.54	2.23	2.25	2.17
22	41	3.60	4.13	2.80	3.00	3.45	4.69	6.16	10.47
23	44	10.84	8.05	5.58	9.43	7.36	6.52	5.53	7.12
24	45	4.28	12.85	11.44	10.40	24.09	8.23	30.73	12.81
25	45	11.05	17.11	9.10	49.36	4.42	4.81	3.50	12.68

TABLE 2. RAW DATA

USE FOR TYPEWRITTEN MATERIAL ONLY

Distance Focus Time (Near - 13")

SUBJECT	AGE	Hi Illumination 30 SEC.	60 SEC.	120 SEC.	240 SEC.	Lo Illumination 30 SEC.	60 SEC.	120 SEC.	240 SEC.
26	47	1.69	2.12	1.82	1.78	1.25	1.75	2.71	1.68
27	49	2.67	2.00	4.12	1.10	1.21	1.35	3.00	3.28
28	50	3.58	4.48	4.43	4.15	4.40	7.75	4.42	25.03
29	50	16.20	21.31	27.38	29.78	25.42	9.10	18.69	36.73
30	50	8.71	14.98	6.52	18.32	18.72	105.45	35.60	40.23
31	51	8.94	3.51	13.21	11.39	5.04	8.64	9.48	31.43
32	51	4.27	4.50	3.80	7.35	6.15	3.75	18.10	13.32
33	52	4.50	5.00	6.40	18.21	35.83	51.43	27.56	53.01
34	53	5.87	5.50	9.11	10.75	21.79	31.68	27.51	15.54
35	53	2.70	3.55	3.76	2.83	19.07	6.23	10.35	4.52

TABLE 2 (Contd.) RAW DATA

USE FOR TYPEWRITTEN MATERIAL ONLY

Distance Focus Time (Near - 26")

		Hi Illumination				Lo Illumination			
SUBJECT	AGE	30 SEC.	60 SEC.	120 SEC.	240 SEC.	30 SEC.	60 SEC.	120 SEC.	240 SEC.
1	22	2.07	2.10	2.26	2.50	2.58	2.48	2.52	6.27
2	22	4.19	3.40	4.14	2.03	3.19	3.11	6.50	4.00
3	24	3.65	2.30	2.67	3.83	2.62	2.15	2.05	2.98
4	24	4.41	3.60	6.90	5.13	6.87	3.19	4.61	7.00
5	25	5.32	5.00	4.79	9.50	3.02	6.35	3.86	3.96
6	26	5.45	3.98	4.72	4.32	4.57	2.86	4.59	3.95
7	27	4.00	3.29	3.75	4.42	3.96	3.77	3.17	6.34
8	28	2.94	2.74	2.48	4.90	3.25	3.35	2.60	3.15
9	29	2.35	3.70	4.59	2.73	8.30	5.09	3.71	10.38
10	30	1.68	1.87	1.61	1.82	1.54	1.56	2.07	1.60
11	31	5.14	5.27	4.37	.876	5.02	6.52	8.36	3.30
12	31	2.08	2.63	1.95	2.04	2.11	1.71	1.96	2.33
13	31	10.30	7.72	14.10	14.38	2.95	6.50	24.20	19.50
14	32	2.10	3.46	3.50	5.03	2.95	3.83	3.71	4.00
15	32	1.51	1.08	1.17	1.29	1.57	2.00	1.05	1.50
16	38	2.29	1.69	1.62	2.68	1.82	1.75	3.22	3.57
17	39	1.11	1.80	1.50	2.54	1.36	1.39	2.39	3.28
18	39	9.54	20.61	4.14	6.40	4.21	12.88	8.27	8.32
19	40	8.11	9.11	12.35	13.35	28.15	26.78	35.93	34.89
20	40	2.68	3.26	2.74	3.23	2.72	2.11	3.06	9.85
21	41	2.44	2.00	2.00	3.18	1.30	2.33	2.07	5.65
22	41	5.45	6.78	8.20	6.68	3.58	1.55	3.68	4.71
23	44	5.00	6.20	9.39	11.00	3.84	6.06	4.47	6.56
24	45	3.28	6.60	5.35	7.50	4.85	9.15	12.35	5.28
25	45	38.19	5.46	41.67	14.11	3.72	4.60	4.19	3.20

TABLE 3. RAW DATA

USE FOR TYPEWRITTEN MATERIAL ONLY

Distance Focus Time (Near - 26")

SUBJECT	AGE	Hi Illumination 30 SEC.	Hi Illumination 60 SEC.	Hi Illumination 120 SEC.	Hi Illumination 240 SEC.	Lo Illumination 30 SEC.	Lo Illumination 60 SEC.	Lo Illumination 120 SEC.	Lo Illumination 240 SEC.
26	47	1.40	1.65	1.35	2.11	2.11	1.85	1.53	2.12
27	49	1.30	1.73	1.86	1.28	2.38	1.21	2.14	4.94
28	50	3.93	6.15	5.48	7.62	4.58	7.95	7.10	7.79
29	50	42.64	32.98	21.24	22.00	24.40	31.06	38.08	29.64
30	50	5.88	11.46	9.16	30.89	25.83	33.29	41.30	35.06
31	51	5.63	9.19	12.20	3.15	4.70	9.11	8.22	38.36
32	51	6.03	18.08	8.13	5.57	7.13	5.28	18.72	4.82
33	52	8.00	7.77	8.00	6.80	27.11	32.76	113.76	57.83
34	53	12.50	12.47	5.56	9.18	10.30	35.90	28.55	45.84
35	53	2.77	2.85	3.93	3.28	6.25	5.93	4.42	4.42

TABLE 3 (Contd.) RAW DATA

USE FOR TYPEWRITTEN MATERIAL ONLY

9.2 SUMMARY OF STATISTICAL RESULTS

Tables 4, 5, 6 qnd 7 are summaries of statistical results obtained for the conditions identified.

It will be noted in this summary of data on accommodation time that the standard deviation is sometimes larger than the mean. This is apparent as accommodation time increases with age. The reason for this is that the distributions are not normal, but positively skewed with some very long accommodation times for the older subjects. In this situation, the mean will be an inflated estimate of the central tendency. However, several potential subjects were dropped from the upper age levels because of advanced presbyopia which prevented them from performing the near task. (It was not practical to provide special bifocal lenses for subjects.) Those that were dropped might be expected to take longer to change accommodation. In any case, if some other measure of central tendency is desired (e.g., median or harmonic mean), this can be computed from the raw data provided in a separate appendix.

Table 4

Subject	Age	Hi Illumination X	Hi Illumination σ	Lo Illumination X	Lo Illumination σ	Both ΣX	Both $ΣX^2$
1	22	2.42	0.24	4.06	2.43	25.92	102.81
2	22	2.67	0.69	4.09	2.29	27.03	108.25
3	24	2.45	0.57	2.20	0.46	18.61	44.62
4	24	5.17	2.07	6.51	1.19	46.73	289.37
5	25	5.26	1.25	4.65	0.85	39.65	202.41
						157.94	747.46
						$\bar{X}$ =	3.95
						σ =	1.80
6	26	3.10	0.32	3.47	1.14	26.29	39.81
7	27	3.68	1.22	5.41	1.17	36.38	177.79
8	28	2.27	1.19	3.91	0.68	24.72	85.98
9	29	3.91	1.47	6.06	4.06	39.85	261.38
10	30	2.17	0.67	2.90	0.95	20.28	55.51
						147 [illegible]	670.47
						$\bar{X}$ =	3.69
						σ =	1.82
11	31	7.00	1.93	5.90	1.21	51.60	346.90
12	31	2.61	2.09	2.65	0.79	21.03	66.53
13	31	9.86	3.54	6.71	7.04	66.30	708.97
14	32	3.08	0.52	3.60	0.27	26.74	90.69
15	32	1.54	0.51	1.85	1.25	13.58	27.35
						179.25	1240.44
						$\bar{X}$ =	4.48
						σ =	3.39
16	38	2.03	0.40	2.69	1.07	18.89	43.42
17	39	2.79	1.92	3.28	1.12	24.28	85.26
18	39	6.50	4.41	6.23	2.67	50.93	384.12
19	40	19.45	11.45	34.78	11.78	216.94	6960.49
20	40	3.33	0.59	2.82	1.13	24.57	69.62
						335.61	7557.91
						$\bar{X}$ =	8.39
						σ =	11.[illegible]

Summary of Statistical Results for the 13-inch Near Vision Task Distance, Two Different Illumination Levels and an Averaged Illumination Level

USE FOR TYPEWRITTEN MATERIAL ONLY

Table 4 (Contd)

Subject	Age	Hi Illumination $\overline{X}$	Hi Illumination σ	Lo Illumination $\overline{X}$	Lo Illumination σ	Both ΣX	Both ΣX^2
21	41	2.24	0.43	2.30	0.59	18.13	41.59
22	41	3.38	0.70	6.19	3.53	38.30	228.33
23	44	8.48	2.59	6.63	0.94	60.43	480.33
24	45	9.74	4.36	18.96	11.88	114.83	2178.96
25	45	21.66	21.69	6.35	4.91	112.03	3149.77
						343.72	6078.98
						$\overline{X}$ =	8.59
						σ =	9.07
26	47	1.85	0.21	1.85	0.71	14.80	28.62
27	49	2.47	1.47	2.21	1.25	18.73	52.36
28	50	4.16	0.47	10.40	11.41	58.24	795.19
29	50	23.67	7.07	22.49	13.42	184.61	4780.47
30	50	12.13	6.31	50.00	44.00	248.53	15034.35
						524.91	20690.99
						$\overline{X}$ =	13.12
						σ =	19.05
31	51	9.26	4.87	13.65	13.87	91.64	1574.25
32	51	4.98	1.86	10.33	7.60	61.24	663.87
33	52	8.53	7.51	41.96	14.25	201.94	7916.26
34	53	7.81	2.94	24.13	8.10	127.75	2739.98
35	53	3.21	0.61	10.19	7.52	53.61	584.85
						536.18	13479.21
						$\overline{X}$ =	13.40
						σ =	12.86
TOTALS						2225.13	50465.46
						$\overline{X}$ =	7.95
						σ =	10.86

USE FOR TYPEWRITTEN MATERIAL ONLY

Table 5

Subject	Age	Hi Illumination $\bar{X}$	Hi Illumination σ	Lo Illumination $\bar{X}$	Lo Illumination σ	Both ΣX	Both ΣX^2
1	22	2.23	0.22	3.46	2.16	22.78	73.52
2	22	3.44	1.16	4.20	1.83	30.56	128.48
3	24	3.11	0.86	2.45	0.50	22.25	64.98
4	24	5.01	1.62	5.42	2.13	41.71	233.97
5	25	6.15	2.59	4.30	1.65	41.80	246.52
						159.10	752.47
						$\bar{X}$ =	3.98
						σ =	1.77
6	26	4.62	0.73	3.99	0.94	34.44	152.22
7	27	3.86	0.54	4.31	1.61	32.70	140.56
8	28	3.26	1.28	3.09	0.39	25.41	84.78
9	29	3.34	1.16	6.87	3.50	40.85	264.04
10	30	1.74	0.13	1.69	0.29	13.75	23.87
						147.15	665.47
						$\bar{X}$ =	3.68
						σ =	1.81
11	31	5.88	2.26	5.80	2.49	46.74	298.52
12	31	2.18	0.36	2.03	0.30	16.81	35.86
13	31	11.62	3.69	13.29	11.75	99.65	1588.12
14	32	3.52	1.38	3.62	0.54	28.58	107.07
15	32	1.26	0.22	1.53	0.45	11.17	16.30
						202.95	2045.87
						$\bar{X}$ =	5.07
						σ =	5.17
16	38	2.07	0.59	2.59	1.09	18.64	47.40
17	39	1.74	0.70	2.10	1.06	15.37	33.42
18	39	10.17	8.43	8.42	4.09	74.37	895.11
19	40	10.73	2.90	31.44	5.36	168.67	4497.38
20	40	2.98	0.36	4.4[illegible]	4.19	29.65	153.9[illegible]
						306.70	5627.30
						$\bar{X}$ =	7.67
						σ =	[illegible]

Summary of Statistical Results for the 20-inch Near Vision Task Distance, Two Different Illumination Levels and an Averaged Illumination Level

Table 5 (Contd)

Subject	Age	Hi Illumination $\bar{X}$	Hi Illumination σ	Lo Illumination $\bar{X}$	Lo Illumination σ	Both ΣX	Both ΣX^2
21	41	2.40	0.64	2.84	2.22	20.97	67.40
22	41	6.78	1.30	3.38	1.53	40.63	238.48
23	44	7.90	3.21	5.23	1.49	52.52	387.09
24	45	5.68	2.11	7.91	4.08	54.36	426.84
25	45	24.86	20.57	3.93	0.70	115.14	3486.56
						283.62	4606.37
						$\bar{X}$ =	7.09
						σ =	8.26
26	47	1.63	0.40	1.90	0.32	14.12	25.67
27	49	1.54	0.34	2.67	1.84	16.84	45.89
28	50	5.80	1.77	6.86	1.80	50.60	336.63
29	50	29.72	11.72	30.80	6.51	242.04	7729.69
30	50	14.35	13.01	33.87	7.35	192.87	5914.31
						516.47	14052.19
						$\bar{X}$ =	12.91
						σ =	13.93
31	51	7.54	4.59	15.10	18.04	90.56	1919.06
32	51	9.45	6.76	8.99	7.58	73.76	912.76
33	52	7.64	0.66	57.86	45.71	262.03	18328.43
34	53	9.93	3.81	30.15	17.33	160.30	4738.25
35	53	3.21	0.61	5.26	1.12	33.85	155.30
						620.50	26053.80
						$\bar{X}$ =	15.51
						σ =	20.79
TOTALS						2236.49	53803.47
						$\bar{X}$ =	7.99
						σ =	11.37

Table 6

Subj.	Age	Hi Illumination ΣX	Hi Illumination ΣX^2	Hi Illumination $\bar{X}$	Hi Illumination σ	Lo Illumination ΣX	Lo Illumination ΣX^2	Lo Illumination $\bar{X}$	Lo Illumination σ
1	22	18.61	43.60	2.33	0.22	30.09	137.73	3.76	2.00
2	22	24.43	79.90	3.05	0.93	33.16	156.83	4.15	1.78
3	24	22.25	65.14	2.78	0.73	18.61	44.46	2.33	0.44
4	24	40.73	223.03	5.09	1.60	47.71	300.31	5.96	1.61
5	25	45.67	280.88	5.71	1.81	35.78	168.05	4.47	1.14
		151.69	692.55	3.79	1.76	165.35	807.38	4.13	1.80
6	26	30.89	125.28	3.86	0.99	29.84	116.75	3.73	0.94
7	27	30.20	118.07	3.78	0.81	38.88	200.28	4.86	1.36
8	28	22.14	70.09	2.77	1.20	27.99	100.67	3.50	0.67
9	29	29.00	113.65	3.63	1.18	51.70	411.77	6.46	3.56
10	30	15.67	32.12	1.96	0.48	18.36	47.26	2.30	0.91
		127.90	459.21	3.20	1.15	166.77	876.73	4.17	2.18
11	31	51.52	354.16	6.44	1.91	46.82	291.26	5.85	1.62
12	31	19.14	56.29	2.39	1.31	18.70	46.10	2.34	0.62
13	31	85.96	988.70	10.75	3.26	79.99	1308.39	10.00	9.11
14	32	26.43	92.61	3.30	0.93	28.89	105.15	3.61	0.37
15	32	11.23	16.61	1.40	0.37	13.52	27.04	1.69	0.83
		194.28	1508.37	4.86	3.85	187.92	1777.94	4.70	4.95
16	38	16.41	34.80	2.05	0.43	21.12	61.02	2.64	0.93
17	39	18.12	52.62	2.27	1.37	21.53	66.06	2.69	1.15
18	39	66.70	786.71	8.34	6.14	58.60	492.52	7.33	3.21
19	40	120.72	2287.62	15.09	8.72	264.89	9170.25	33.11	8.[illegible]
20	40	25.22	80.81	3.15	0.46	29.00	152.80	3.63	2.79
		247.17	3242.56	6.18	6.72	395.14	9942.65	9.88	12.63

Summary of Statistical Results for an Averaged Work Distance at Two Different Illumination Levels

USE FOR TYPEWRITTEN MATERIAL ONLY

Table 6 (Contd)

Subj.	Age	Hi Illumination ΣX	Hi Illumination ΣX^2	Hi Illumination $\overline{X}$	Hi Illumination σ	Lo Illumination ΣX	Lo Illumination ΣX^2	Lo Illumination $\overline{X}$	Lo Illumination σ
21	41	18.56	44.46	2.32	0.48	20.54	64.53	2.57	1.39
22	41	40.64	234.39	5.08	2.14	38.29	232.42	4.79	2.83
23	44	65.49	574.98	8.19	2.52	47.46	292.44	5.93	1.33
24	45	61.70	561.66	7.71	3.74	107.49	2044.14	13.44	9.90
25	45	186.05	6357.34	23.26	18.21	41.12	278.49	5.14	3.31
		372.44	7773.33	9.31	10.64	254.90	2912.02	6.37	5.82
26	47	13.92	24.79	1.74	0.30	15.00	29.50	1.88	0.47
27	49	16.06	39.09	2.01	1.06	19.51	59.16	2.44	1.37
28	50	39.82	211.09	4.98	1.45	69.02	920.73	8.63	7.29
29	50	213.53	6194.06	26.69	8.99	213.12	6316.10	26.64	10.21
30	50	105.92	1882.40	13.24	8.85	335.48	19066.26	41.94	28.57
		389.25	8351.43	9.73	10.96	652.13	26391.75	16.30	20.36
31	51	67.22	671.40	8.40	4.17	114.98	2821.91	14.37	13.82
32	51	57.73	567.32	7.22	4.96	77.27	1009.31	9.66	6.55
33	52	64.68	652.42	8.09	4.60	399.29	25592.27	49.91	30.41
34	53	70.94	690.20	8.87	3.16	217.11	6788.03	27.14	12.09
35	53	25.67	84.04	3.21	0.52	61.79	656.11	7.72	5.40
		286.24	2665.38	7.16	4.03	870.44	36867.63	21.76	21.71
TOTALS		1768.97	24692.83	6.32	6.97	2692.65	79576.10	9.62	13.90

USE FOR TYPEWRITTEN MATERIAL ONLY

Table 7

Subj.	Age	13" $\bar{X}$	13" σ	26" $\bar{X}$	26" σ	Sum All Conditions by Subject $\Sigma\Sigma X$	$\Sigma\Sigma X^2$	$\bar{X}$	σ
1	22	3.24	1.75	2.85	1.49	48.70	181.33	3.04	1.53
2	22	3.38	1.66	3.82	1.38	57.59	236.73	3.60	1.45
3	24	2.33	0.47	2.78	0.71	40.86	109.60	2.55	0.61
4	24	5.84	1.64	5.21	1.64	88.44	523.34	5.53	1.57
5	25	4.96	0.98	5.23	2.14	81.45	448.93	5.09	1.56
	23.4					317.04	1499.93	3.96	1.77
6	26	3.29	0.75	4.31	0.80	60.73	242.03	3.80	0.91
7	27	4.55	1.42	4.09	1.06	69.08	318.35	4.32	1.20
8	28	3.09	1.25	3.18	0.82	50.13	170.76	3.13	0.99
9	29	4.98	3.20	5.11	3.01	80.70	525.42	5.04	2.90
10	30	2.54	0.82	1.72	0.20	34.03	79.38	2.13	0.71
	28.0					294.67	1335.94	3.68	1.79
11	31	6.45	1.52	5.84	2.04	98.34	645.42	6.15	1.71
12	31	2.63	1.36	2.10	0.30	37.84	102.39	2.37	0.96
13	31	8.29	5.10	12.46	7.53	165.95	2297.09	10.37	6.40
14	32	3.34	0.46	3.57	0.90	55.32	197.76	3.46	0.68
15	32	1.70	0.84	1.40	0.34	24.75	43.65	1.55	0.62
	31.4					382.20	3286.31	4.78	[illegible].33
16	38	2.36	0.79	2.33	0.80	37.53	95.82	2.35	0.74
17	39	3.04	1.37	1.92	0.80	39.65	118.68	2.48	1.21
18	39	6.37	3.13	9.30	5.77	125.30	1279.23	7.83	4.60
19	40	27.12	13.26	21.08	12.40	385.61	11457.87	24.10	12.41
20	40	3.07	0.82	3.71	2.68	54.22	233.61	3.39	1.88
	39.2					642.31	13185.21	8.03	10.14

Summary of Statistical Results - Sum of All Conditions by Subject

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Table 7 (Contd)

		13"		26"		Sum All Conditions by Subject			
Subj.	Age	$\overline{X}$	σ	$\overline{X}$	σ	$\Sigma\Sigma X$	$\Sigma\Sigma X^2$	$\overline{X}$	σ
21	41	2.27	0.29	2.62	1.42	39.10	108.99	2.44	0.98
22	41	4.79	2.71	5.08	2.29	78.93	466.81	4.93	2.35
23	44	7.55	1.97	6.57	2.63	112.95	867.42	7.06	2.23
24	45	14.35	9.31	6.80	3.06	169.19	2605.80	10.57	7.62
25	45	14.00	16.07	14.39	17.28	227.17	6636.33	14.20	15.57
	43.2					627.34	10685.35	7.84	8.60
26	47	1.85	0.45	1.77	0.35	28.92	54.29	1.81	0.38
27	49	2.34	1.18	2.11	1.31	35.57	98.25	2.22	1.17
28	50	7.28	7.78	6.33	1.65	108.84	1131.82	6.80	5.28
29	50	23.08	9.22	30.26	8.15	426.65	12510.16	26.67	8.98
30	50	31.07	34.55	24.11	14.37	441.40	20948.66	27.59	24.93
	49.2					1041.38	34743.18	13.02	16.48
31	51	11.46	9.25	11.32	12.08	182.20	3493.31	11.39	10.04
32	51	7.66	5.64	9.22	6.16	135.00	1576.63	8.44	5.58
33	52	25.24	21.45	32.75	39.89	463.97	26244.69	29.00	30.16
34	53	15.97	10.69	20.04	15.79	288.05	7478.23	18.00	12.77
35	53	6.70	6.07	4.23	1.40	87.46	740.15	5.47	4.32
	52.0					1156.68	39533.01	14.46	17.10
TOTALS						4461.62	104268.93	7.97	11.10

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9.3 RAW DATA - SUBJECTIVE SENSITIVITY TO CHANGES IN OCULAR FOCUS

Tables 8 through 14 illustrate levels of subjective awareness to low power spherical lens induced changes in ocular focus for different age groups.

Table 8

* - Subject's Age
** - Subject's Dominant Eye

Subjects	Best Lens Correction (LASER)	Subjective Awareness of Changes in Focus Caused by Monocular Alterations during Binocular Viewing of the LASER Image			
		+0.25	-0.25	+0.37	-0.37
1. 22*					
(R. Eye)**	Plano	Yes	Yes	Yes	Yes
L. Eye	Plano - .25 x 180	Yes	No	Yes	Yes
2. 22					
(R. Eye)	+0.37 - .25 x 130	No	No	Yes	Yes
L. Eye	+0.25 - .25 x 160	No	No	Yes	Yes
3. 24					
(R. Eye)	+0.25 - .25 x 100	No	No	Yes	Yes
L. Eye	+0.37 - .25 x 70	No	No	Yes	Yes
4. 24					
R. Eye	-0.87 - .50 x 90	Yes	Yes	Yes	Yes
(L. Eye)	-1.00 - .25 x 95	Yes	Yes	Yes	Yes
5. 25					
(R. Eye)	-1.37	Yes	Yes	Yes	Yes
L. Eye	-1.37	No	No	No	No

Subjective Awareness to Low Power Spherical Lens Induced Changes in Ocular Focus for the 20-25 Year Old Group

Table 9

* - Subject's Age
** - Subject's Dominant Eye

Subjects	Best Lens Correction (LASER)	Subjective Awareness of Changes in Focus Caused by Monocular Alterations during Binocular Viewing of the LASER Image			
		+0.25	-0.25	+0.37	-0.37
6. 26*					
(R. Eye)**	Plano - .75 x 95	No	No	Yes	No
L. Eye	Plano - .75 x 95	No	No	No	No
7. 27					
(R. Eye)	-0.75 - .25 x 180	Yes	Yes	Yes	Yes
L. Eye	-1.25 - .25 x 165	Yes	Yes	Yes	Yes
8. 28					
(R. Eye)	Plano - .25 x 90	Yes	Yes	Yes	Yes
L. Eye	Plano	Yes	Yes	Yes	Yes
9. 29					
(R. Eye)	-2.50 - .25 x 95	No	No	Yes	Yes
L. Eye	-2.25 - .25 x 125	No	No	Yes	Yes
10. 30					
(R. Eye)	Plano	No	No	Yes	No
L. Eye	Plano	No	No	Yes	No

Subjective Awareness to Low Power Spherical Lens Induced Changes in Ocular Focus for the 26-30 Year Old Group

Table 10

* - Subject's Age
** - Subject's Dominant Eye

Subjects	Best Lens Correction (LASER)	Subjective Awareness of Changes in Focus Caused by Monocular Alterations during Binocular Viewing of the LASER Image			
		+0.25	-0.25	+0.37	-0.37
11. 31*					
(R. Eye)**	Plano - .75 x 80	Yes	Yes	Yes	Yes
L. Eye	-0.37 - .50 x 95	Yes	Yes	Yes	Yes
12. 31					
(R. Eye)	-3.00 - .25 x 165	No	Yes	Yes	Yes
L. Eye	-3.37	Yes	Yes	Yes	Yes
13. 31					
(R. Eye)	Plano - .25 x 65	Yes	Yes	Yes	Yes
L. Eye	Plano - .25 x 110	Yes	Yes	Yes	Yes
14. 32					
(R. Eye)	-0.37 - .25 x 75	No	No	Yes	Yes
L. Eye	-0.37 - .50 x 125	No	No	No	Yes
15. 32					
R. Eye	Plano - .25 x 90	Yes	Yes	Yes	Yes
(L. Eye)	-0.25 - .25 x 90	Yes	Yes	Yes	Yes

Subjective Awareness to Low Power Spherical Lens Induced Changes in Ocular Focus for the 31-35 Year Old Group

Table 11

* - Subject's Age
** - Subject's Dominant Eye

Subjects	Best Lens Correction (LASER)	Subjective Awareness of Changes in Focus Caused by Monocular Alterations during Binocular Viewing of the LASER Image			
		+0.25	-0.25	+0.37	-0.37
16. 38*					
R. Eye **	-1.75 -2.50 x 35	No	No	No	Yes
(L. Eye)	-1.87 -2.00 x 175	No	No	Yes	Yes
17. 39					
(R. Eye)	+0.50 - .50 x 175	Yes	Yes	Yes	Yes
L. Eye	+0.12 - .25 x 10	Yes	Yes	Yes	Yes
18. 39					
(R. Eye)	+0.75 - .25 x 65	Yes	Yes	Yes	Yes
L. Eye	+0.50 - .50 x 165	No	No	No	Yes
19. 40					
(R. Eye)	+0.75 - .25 x 90	Yes	Yes	Yes	Yes
L. Eye	+0.75 - .75 x 90	Yes	Yes	Yes	Yes
20. 40					
(R. Eye)	-0.25 - .25 x 150	No	Yes	No	Yes
L. Eye	-1.50	No	No	No	Yes

Subjective Awareness to Low Power Spherical Lens Induced Changes in Ocular Focus for the 36-40 Year Old Group

Table 12

* - Subject's Age
** - Subject's Dominant Eye

Subjects	Best Lens Correction (LASER)	Subjective Awareness of Changes in Focus Caused by Monocular Alterations during Binocular Viewing of the LASER Image			
		+0.25	-0.25	+0.37	-0.37
21. 41*					
(R. Eye)**	+0.62	No	No	Yes	Yes
L. Eye	+0.62	-	-	-	-
22. 41					
(R. Eye)	-3.50 - .75 x 15	No	Yes	No	Yes
L. Eye	-3.50 - .75 x 165	-	-	-	-
23. 44					
(R. Eye)	-0.75 - .75 x 180	No	Yes	No	Yes
L. Eye	-0.50 -1.50 x 145	-	-	-	-
24. 45					
(R. Eye)	-5.00 - .25 x 10	Yes	Yes	Yes	Yes
L. Eye	-4.75 - .37 x 175	Yes	Yes	Yes	Yes
25. 45					
(R. Eye)	-0.25 - .50 x 135	No	Yes	No	Yes
L. Eye	-0.50 -1.00 x 45	-	-	-	-

Subjective Awareness to Low Power Spherical Lens Induced Changes in Ocular Focus for the 41-45 Year Old Group

Table 13

* - Subject's Age
** - Subject's Dominant Eye

Subjects	Best Lens Correction (LASER)	Subjective Awareness of Changes in Focus Caused by Monocular Alterations during Binocular Viewing of the LASER Image			
		+0.25	-0.25	+0.37	-0.37
26. 47*					
(R. Eye)**	+0.25 -1.00 x 95	No	No	No	No
L. Eye	Plano - .25 x 75	No	No	No	No
27. 49					
(R. Eye)	+0.12 - .75 x 10	Yes	Yes	Yes	Yes
L. Eye	+0.25 - 1.00 x 170	No	No	Yes	No
28. 50					
R. Eye	+1.75	Yes	Yes	Yes	Yes
L. Eye	+1.75 - .25 x 100	-	-	-	-
29. 50					
(R. Eye)	+0.75 - .50 x 170	No	No	No	No
L. Eye	+0.75 - .25 x 135	No	No	No	No
30. 50					
(R. Eye)	-1.62 - .25 x 165	No	Yes	Yes	Yes
L. Eye	-1.87 - .75 x 05	No	Yes	Yes	Yes

Subjective Awareness to Low Power Spherical Lens Induced Changes in Ocular Focus for the 46-50 Year Old Group

Table 14

* - Subject's Age
** - Subject's Dominant Eye

Subjects	Best Lens Correction (LASER)	Subjective Awareness of Changes in Focus Caused by Monocular Alterations during Binocular Viewing of the LASER Image			
		+0.25	-0.25	+0.37	-0.37
31. 51*					
R. Eye **	Plano -1.25 x 105	-	-	-	-
(L. Eye)	-0.37 -1.25 x 75	Yes	Yes	Yes	Yes
32. 51					
(R. Eye)	-0.12 - .25 x 70	No	No	Yes	Yes
L. Eye	-0.62 - .50 x 170	No	No	Yes	Yes
33. 52					
(R. Eye)	-0.50 - .50 x 125	No	No	Yes	Yes
L. Eye	-0.75 - .25 x 95	No	No	Yes	Yes
34. 53					
(R. Eye)	Plano	No	Yes	No	Yes
L. Eye	-0.37	-	-	-	-
35. 53					
R. Eye	+0.50 - .50 x 170	-	-	-	-
(L. Eye)	+0.12	No	No	No	No

Subjective Awareness to Low Power Spherical Lens Induced Changes in Ocular Focus for the 51-55 Year Old Group

9.4 LASER OPTOMETER

Although the laser had been used to measure the refractive state of the eye before, the specific impetus for its application to the present problem stemmed from a visit of the second author to the laboratory of R. T. Hennessy and H. W. Leibowitz at Pennsylvania State University (see references below).

The laser used in this study was a helium-neon (HeNe) gas laser with a power rating of one milliwatt. HeNe lasers emit light in a very narrow spectral band (633 nanometers). It was expected that monochromatic light from one end of the visible spectrum might be associated with a refractive state which would differ from that evidenced in white light. However, results of tests with the laser optometer were no greater than one eighth diopter different from the results obtained (by the senior author who is a qualified optometrist) with standard clinical refraction techniques.

Subjects were provided any correction needed, spherical or cylindrical, to permit them to perceive random, non-directional motion in the laser optometer located 20 feet from the subject. There was no attempt to assure precise accommodation for the near task or to measure it. However, the subject did have to accommodate sufficiently to read the printed material used for the near task.

The small (1 cm) beam of light was diverged by a lens in front of the laser and cast on a drum which rotated at approximately one-sixth cycle per hour. The laser scintillation pattern is due to the reflected laser light from the curved surface of the drum.

In no instant did the subject look directly at the light as it came from the laser. The laser optometer was constructed so that no direct viewing of the laser was possible.

It is important to note that the laser scintillation pattern is not a stimulus to accommodation. The light granules in the scintillation pattern are distinct whether one is accommodated for the drum or for some other distance. There is some unidirectional flow when the drum is revolving if the eye is accommodated for some other distance. Because the laser scintillation pattern is not a stimulus to accommodation, the drum was framed by a high contrast target of alternating white and black bars oriented obliquely. This accommodation target was given its own independent illumination.

Another aspect of the appearance of the laser scintillation pattern deserves mention. The granules appear larger when seen through a small aperture. Thus, under high ambient light where the pupil of the eye is more constricted, the granules appear larger than under low ambient light where the pupil is larger. Subjectively, the task of reporting when the directional motion of the granules has changed to a random motion is easier when the granules are larger. Therefore, deciding when this change occurs could be more difficult under low illumination, with a corresponding increase in reported accommodation time.

ACTIVE SHEET RECORD

SHEET NUMBER	REV LTR	ADDED SHEETS SHEET NUMBER	REV LTR	ADDED SHEETS SHEET NUMBER	REV LTR
1					
1a					
2					
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4					
5					
6					
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9					
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11					
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SHEET NUMBER	REV LTR	ADDED SHEETS SHEET NUMBER	REV LTR	ADDED SHEETS SHEET NUMBER	REV LTR
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REVISIONS			
LTR	DESCRIPTION	DATE	APPROVAL